Australia's National Science Agency

Toward an Australian National Coastal Model

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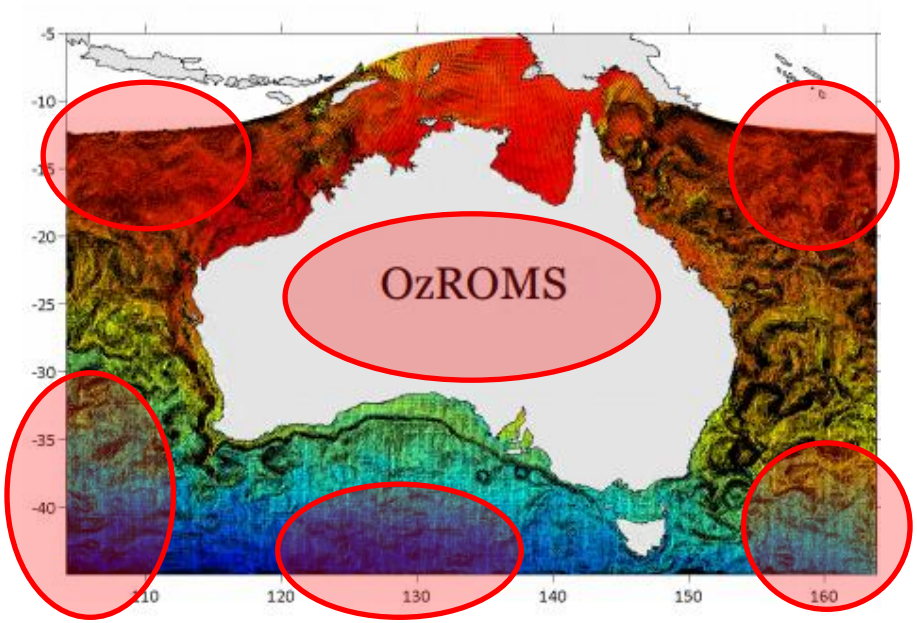
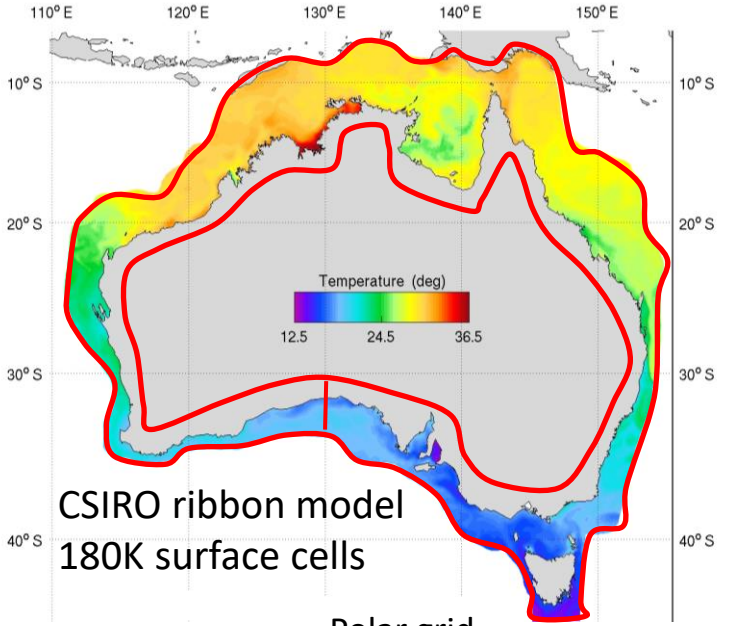
National Coastal Modelling Systems

- Model resolution of < 1 km is required to capture coastal phenomena and sub-mesoscale dynamics.
- Numerous limited area coastal models are in operation around Australia.
- An Australian National Coastal Modelling System at the 1 km scale currently does not exist.
- Existing national models do not adequately resolve coastal regions
  - OceanMAPS
  - ozROMS
  - CSIRO Ribbon Model
  - ANSR initiative – unconnected ‘system of systems’ approach.

Rectangular national domains are computationally inefficient for coastal models



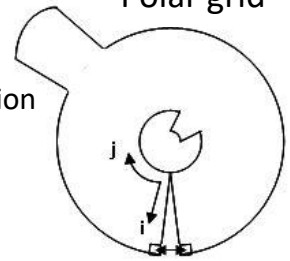
ozROMS
4.7 million surface cells



CSIRO ribbon model
180K surface cells

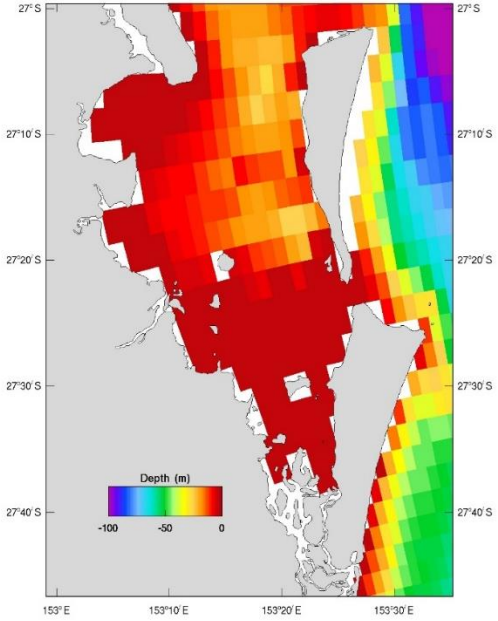
- Join is difficult
- Can't control resolution

Polar grid

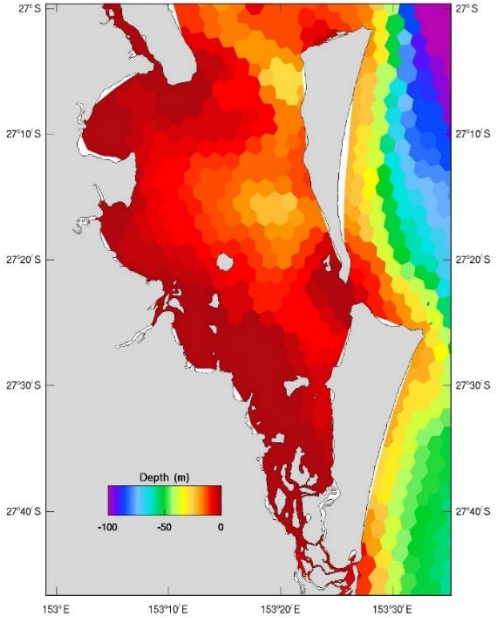


Unstructured modelling approach

- Structured (rectangular grid) models are sub-optimum for coastal modelling at the national scale
- Recent advances in unstructured (polygonal mesh) modelling provide alternative pathways



Structured



Unstructured

- Uses boundary fitted mesh in a concave hull
- Benefits of a polar grid without a join
- Superior resolution placement
- Superior resolution transition
- Leads to superior computational efficiency

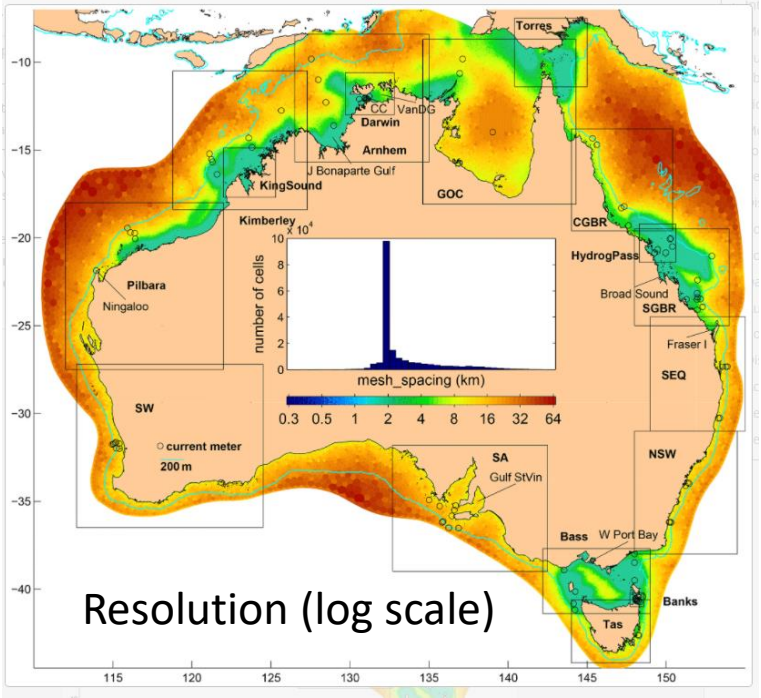
COMPAS (Coastal Ocean Marine Prediction Across Scales)

- COMPAS is an unstructured coastal model based on TRiSK numerics used in the MPAS-O global ocean model (developed at LANL)
- Developed at CSIRO for coastal applications
- Uses Voronoi diagram meshes (dual of a Delaunay triangulation)
  - Hexagons for perfect Delaunay triangles
- High order FFSL tracer advection
- Mesh generation coupled to JIGSAW inline
- Model described in:

  Herzfeld, M., Engwirda, D., Rizwi, F. (2020) A coastal unstructured model using Voronoi meshes and C-grid staggering. Ocean Modelling, 148, 101599. https://doi.org/10.1016/j.ocemod.2020.101599
- Beta version available on GitHub: https://github.com/csiro-coasts/EMS

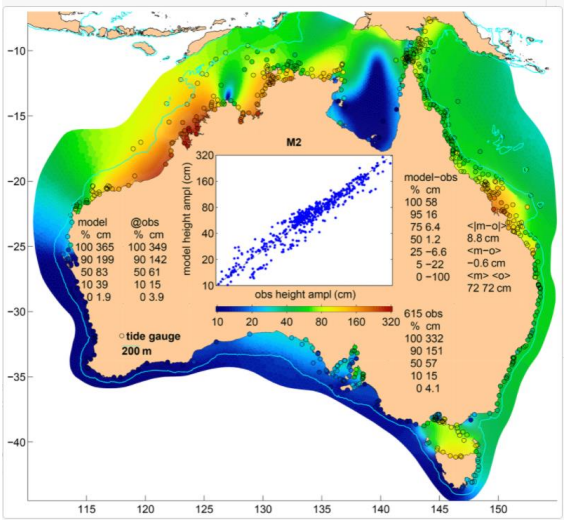
Applied to national tidal model (ARENA)

- Griffin, D. A., Herzfeld, M., Hemer, M., Engwirda, D. (2021) Australian tidal currents – assessment of a barotropic model (COMPAS v1.3.0 rev6631) with an unstructured grid, Geosci. Model Dev., 14, 5561–5582, https://doi.org/10.5194/gmd-14-5561-2021

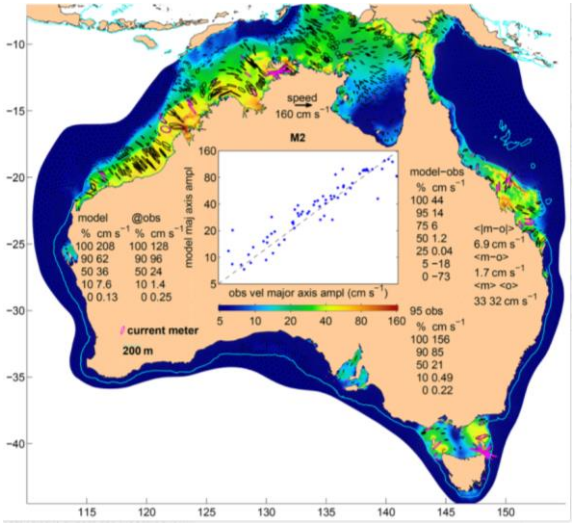


- Mesh uses a weighting function based on gravity wave speed (bathymetry) and tidal velocity
- Shallow areas with high tidal flow receive high resolution
- 183810 surface cells
- Model run in barotropic model only
- Forced with 8 tidal constituents from TPXO9v1 1/6° global tide model
- Compared to 64 ADCP, 635 sea level sites

Comparison results

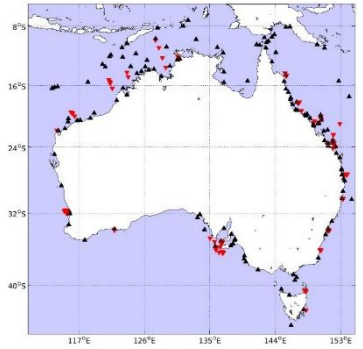


M2 tidal height



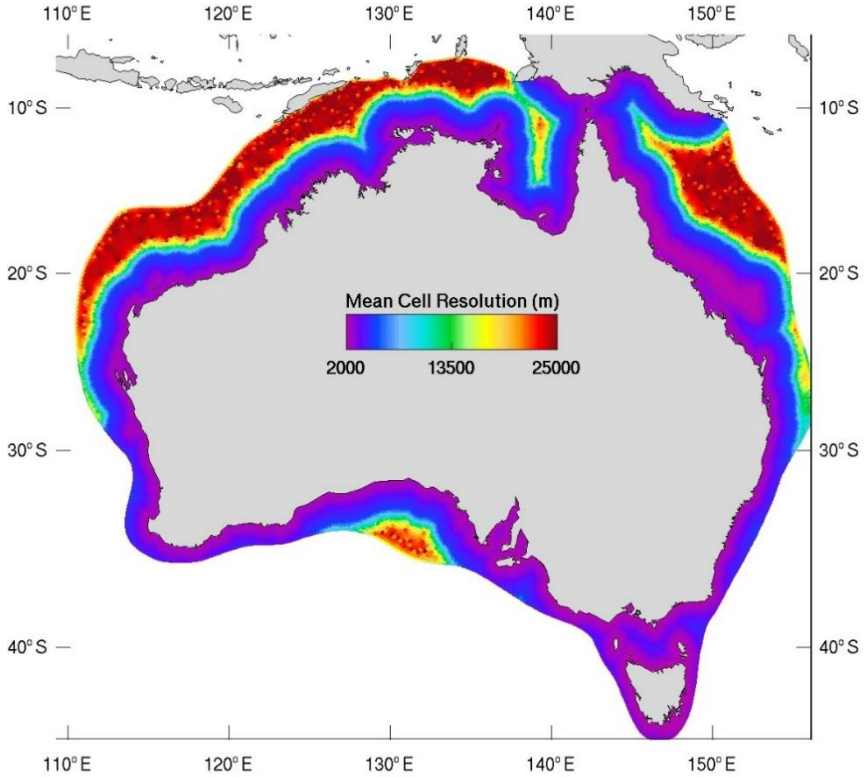
M2 tidal velocity

- Compared to 64 ADCP, 635 sea level sites



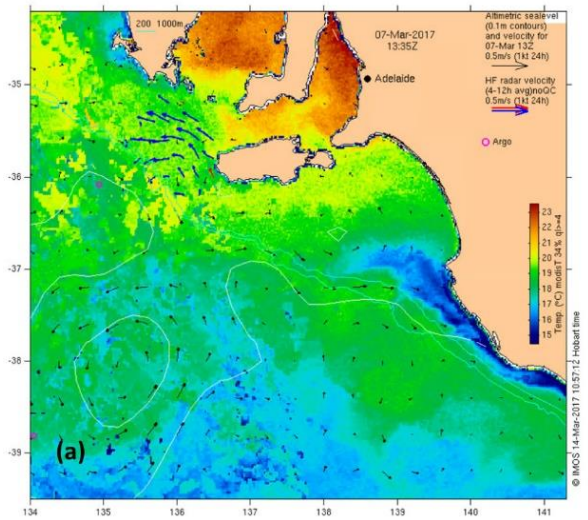
- ARENA model tidal height errors almost double TPXO errors
- ARENA model velocity errors half TPXO errors
- Pretty good – TPXO is data assimilating, ARENA is not
- A viable national model can be developed using COMPAS

Extend to 3D baroclinic model – 2 km

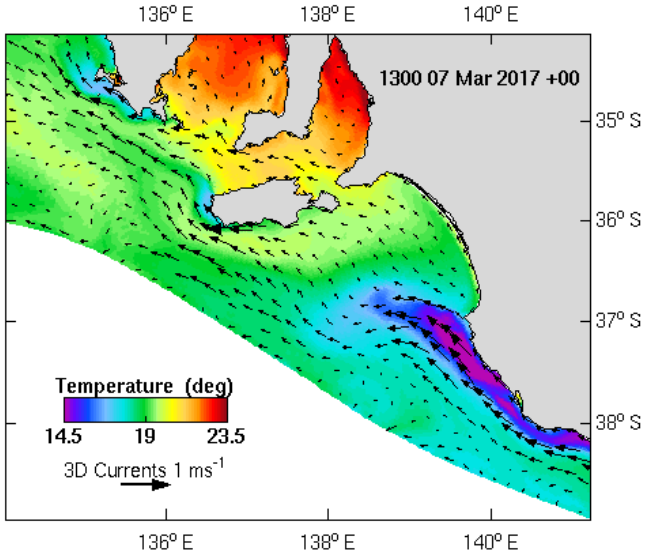


- Use distance-from-the-coast weighting
- Number of 2D wet cells = **433,761**
- Number of 3D wet cells = 6,382,240
- 53 vertical layers
- Mean horizontal edge length = **1713** m
- Mean distance between centres = 2982 m
- Minimum distance between centres = 155 m
- Maximum distance between centres = 32184 m
- OBCs forced with TPXO tide, OceanMAPS global model
- Surface forced with ACCESS momentum, heat & freshwater fluxes
- No freshwater inflows

Example output : Bonney Coast upwelling

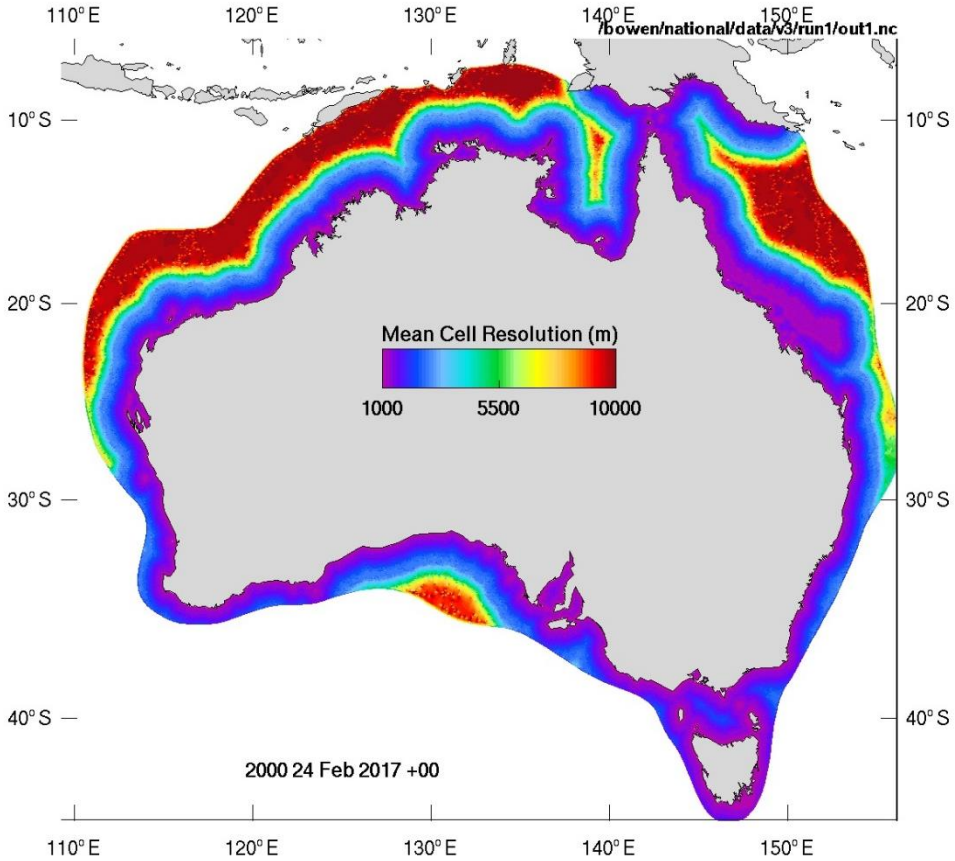


SST from IMOS OceanCurrent



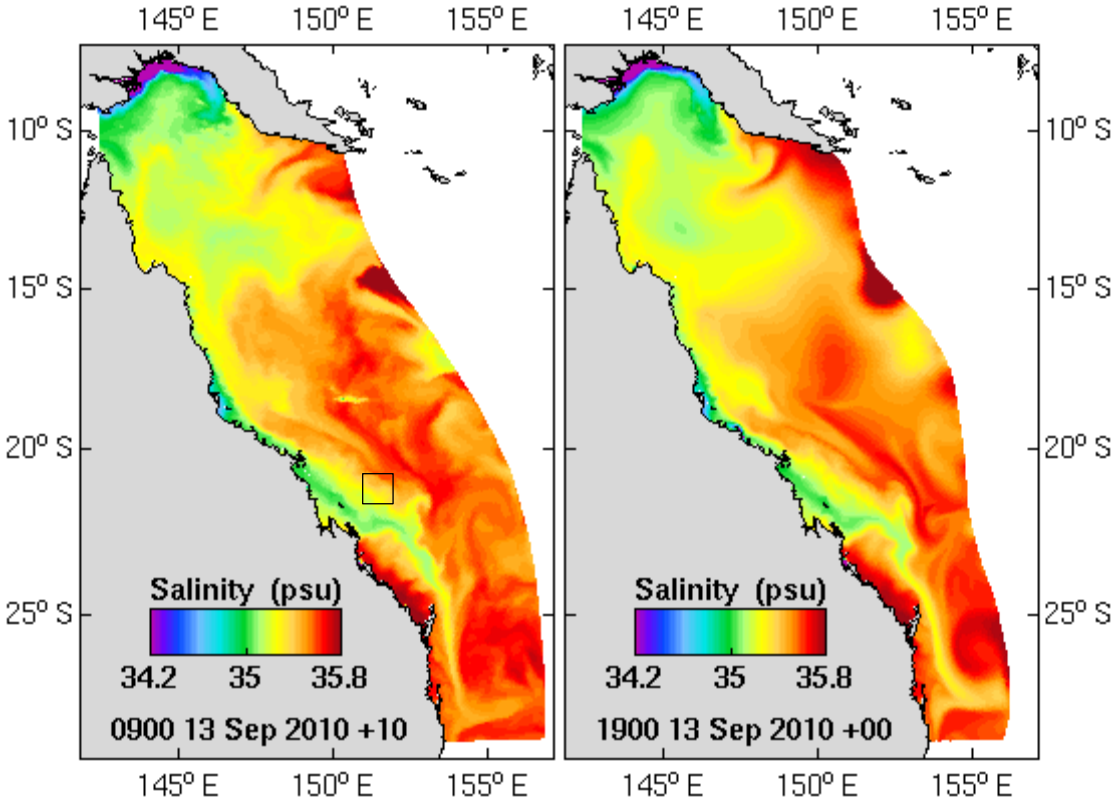
COMPAS v2.95 (2 km model)

Extend to 3D baroclinic model – 1 km



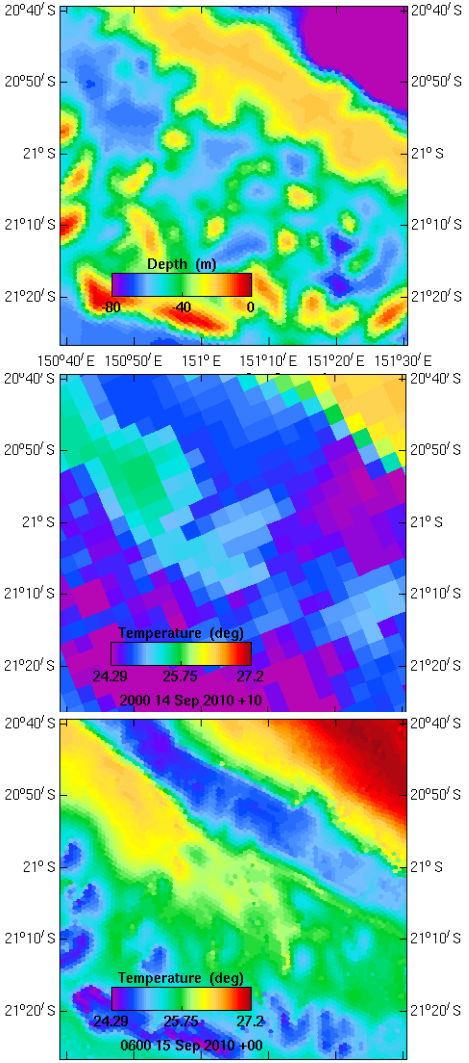
- Use distance-from-the-coast weighting
- Number of 2D wet cells = **1,259,516**
- Number of 3D wet cells = 21,178,696
- 53 vertical layers
- Mean horizontal edge length = **1032** m
- Mean distance between centres = 1792 m
- Minimum distance between centres = 132 m
- Maximum distance between centres = 13488 m
- OBCs forced with TPXO tide, OceanMAPS global model
- Surface forced with ACCESS momentum, heat & freshwater fluxes
- Only 4 riverine inputs so far

Comparison to eReefs (www.ereefs.info)



eReefs 4 km

National 1 km



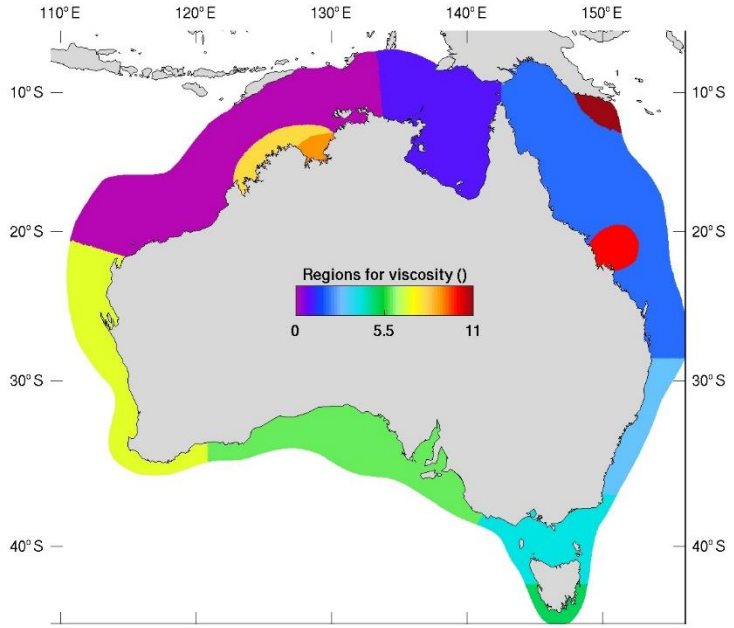
Bathymetry

eReefs Temperature

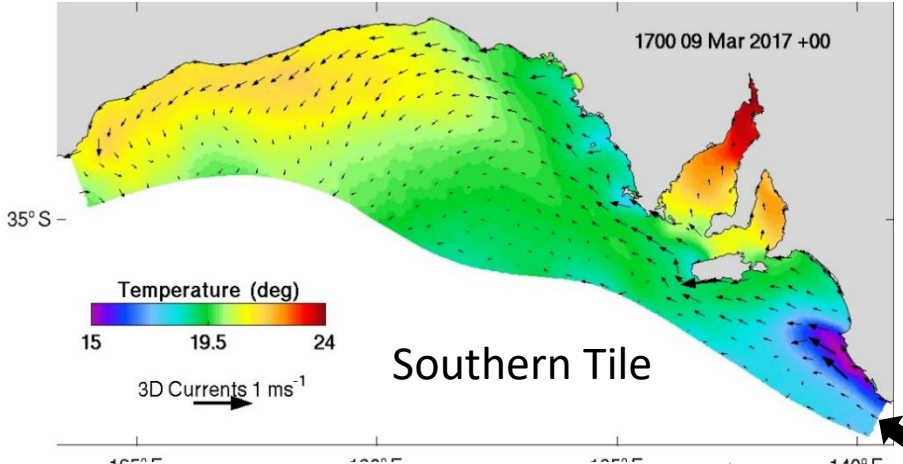
National Temperature

Parameter regionalization is required

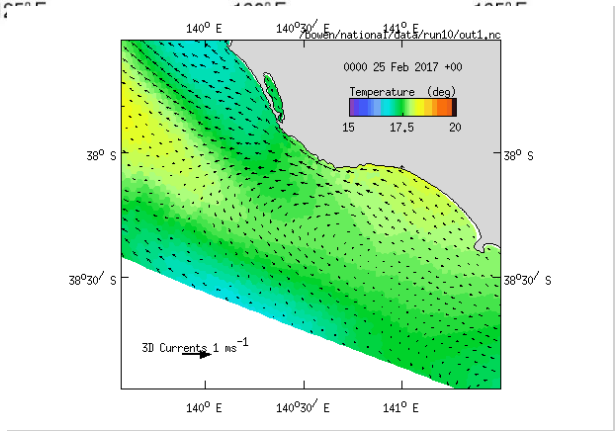
- Australia has ~34,000 km of coast
- EEZ = 8.2×10^6 km^2 (3^{rd} largest)
- The Australian shelves contain a spectrum of dynamics
  - ~12 m tidal range in King William Sound (west coast), 9 m in Broad Sound (east coast)
  - 2 boundary currents (East Australian Current, Leeuwin Current)
  - Coastally trapped waves, upwelling, ROFIs, mesoscale eddies etc.
- Often a single parameterisation (e.g. friction) cannot represent the spectrum of dynamics
- Regionalize horizontal mixing (base rates), bottom drag (roughness length)



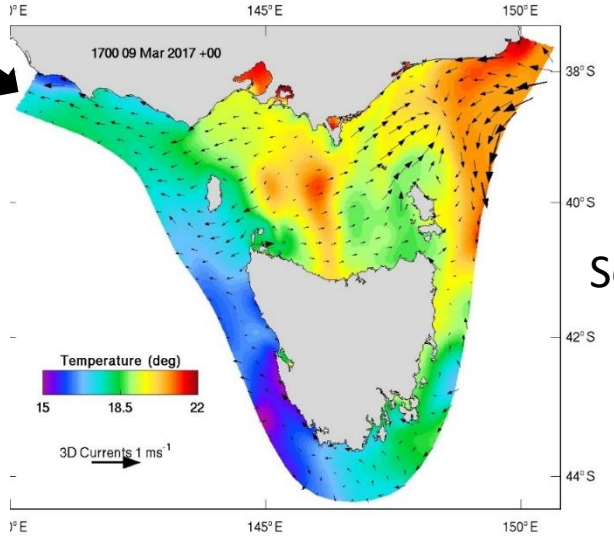
Piecewise approach to modelling nationally



Southern Tile



- Decompose the model into ‘tiles’
- 2-way coupling between tiles
- Each tile is independently optimized
- Tiles may be run in isolation (greater throughput)



South Eastern Tile

Conclusions

- Unstructured approaches are a ideally suited for modelling Australia's coasts at the national scale
- COMPAS has successfully been applied as a national tide model
- A 3D baroclinic model at ~1 km coastal resolution looks promising
  - Still computationally heavy – throughput is an issue
    - Development required for parallel optimization
  - Regionalized parameterisations are challenging

Thank you

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